

II. ANALYSIS METHODS

This study uses the DRIs to assess the nutrient adequacy of the diets of population subgroups at risk of either inadequate or excessive intake levels. Nutrient adequacy involves determining whether the diets of the various subgroups meet their nutrient requirements without being excessive. This chapter first describes the DRIs, then presents the research questions and methods used to address them.

A. DIETARY REFERENCE INTAKES

The DRIs for micronutrients include four reference standards—the Estimated Average Requirement (EAR), the Recommended Dietary Allowance (RDA), the Adequate Intake (AI), and the Tolerable Upper Intake Level (UL) (see Table 2). When sufficient information is available on the distribution of nutrient requirements, a nutrient will have an EAR and an RDA. When information is not sufficient to determine an EAR (and, thus, an RDA), then an AI is set for the nutrient. In addition, many nutrients have a UL. For some nutrients, however, data are not sufficient to estimate the UL reliably. The absence of a UL does not imply that the nutrient does not have a tolerable upper intake level, but, rather, that the available evidence at this times does not permit its estimation.

Table 2: Dietary Reference Intakes

Estimated Average Requirement (EAR): usual intake level that is estimated to meet the requirement of half the healthy individuals in a life stage and gender group. At this level of intake, the other half of the healthy individuals in the specified group would not have their needs met.

Recommended Dietary Allowance (RDA): usual intake level that is sufficient to meet the nutrient requirement of nearly all healthy individuals in a particular age and gender group (97.5 percent of the individuals in a group). If the distribution of requirements in the group is assumed to be normal, the RDA can be derived as the EAR plus two standard deviation of requirements.

Adequate Intake (AI): usual intake level based on experimentally derived intake levels or approximations of observed mean nutrient intakes by a group (or groups) of apparently healthy people who are maintaining a defined nutritional state or criterion of adequacy –used when an EAR and RDA cannot be determined.

Tolerable Upper Intake Level(UL): highest level of usual nutrient intake that is likely to pose no risks of adverse health effects to individuals in the specified life stage group. As intake increases above the UL, the risk of adverse effects increases.

Source: Institute of Medicine, *Dietary Reference Intakes: Applications in Dietary Assessment*. Washington, DC: National Academies Press, 2000a.

For macronutrients and fiber, a somewhat different set of DRIs have been developed (Institute of Medicine 2002). In the case of food energy, dietary requirements are expressed in terms of estimated energy requirements (EERs). An adult EER is defined as the dietary energy intake needed to maintain energy balance in a healthy adult of a given age, gender, weight, height, and level of physical activity. In children, the EER is defined as the sum of the dietary energy intake predicted to maintain energy balance for an individual's age, weight, height, and activity level, plus an allowance for normal growth and development. For fat, protein, and carbohydrate, the DRIs include Acceptable Macronutrient Distribution Ranges (AMDRs) for intakes as a percentage of energy intakes. In addition, the DRIs for carbohydrate and protein include an EAR and an RDA. For fiber, the DRI is expressed as an AI.

B. STUDY QUESTIONS AND METHODOLOGICAL APPROACH

Table 3 provides an overview of the main study questions and outcome measures used in the analysis. The following discussion provides additional detail on this table.

Table 3: Research Questions and Outcome Measures

Outcome Measures	Comments
<i>What are the characteristics of the distribution of usual intake of the high-needs subgroups?</i>	
Mean and median usual nutrient intake Percentiles of the usual nutrient intake distribution	For energy, mean usual intake will be compared with the mean EER for each age/gender subgroup. For nutrients with an AI, mean intake will be compared with the AI.
<i>What proportion of the subgroup has inadequate usual intake?</i>	
Percentage with usual intake < EAR Percentage with usual fat, protein, and carbohydrate intakes outside the AMDR	Measures cannot be used for nutrients for which an EAR has not been determined. For iron in women, prevalence of inadequacy must be estimated using the probability approach (NRC 1986).
<i>What proportion of the subgroup is at risk of excessive intake levels?</i>	
Percentage with usual intake > UL	Measure cannot be used for nutrients for which a UL has not yet been determined.
<i>How does the day-to-day variation in nutrient intake vary across subgroups?</i>	
Estimate of the within-person standard deviation in intake	Of particular interest are the differences in day-to-day variability in intakes across population subgroups

1. What Are the Characteristics of the Distribution of Usual Intake?

In order to describe the characteristics of the usual intake distribution, and to use the DRIs in assessing diets, it is important to have a good estimator for the distribution of usual nutrient intakes in the group. The usual intake of a nutrient is defined as the long-run average intake of the nutrient by the individual (National Research Council [NRC] 1986). Usual intake seldom, if ever, can be observed. Rather, dietary recalls provide data on observed nutrient intakes over some specified period of time. Observed daily intake measures individual usual intake with error. That is, nutrient intake varies from individual to individual in the group, but it also varies from day to day within an individual. The day-to-day variability is “noise,” since what we are typically interested in is the individual-to-individual variability in usual nutrient intake. Because for most nutrients, the day-to-day variability in intakes can be larger than the individual-to-individual variability, it is very important to “remove” the effect of this additional variability when estimating the distribution of usual intakes (Beaton et al. 1979).

A simple additive measurement error model that permits adjusting the data for the presence of day-to-day variability was proposed by the NRC (1986). The model proposed by NRC simply posits that the observed daily intake for an individual can be written as a deviation from the individual’s usual intake. That is:

$$X_{ij} = x_i + e_{ij},$$

where X_{ij} denotes the observed intake for individual i on day j , x_i denotes the usual intake of the nutrient by individual i , and e_{ij} is the measurement error associated with that individual on that day. In the NRC report, it was assumed that the mean of the distribution of measurement errors is zero, so that the expectation of the daily intakes (conditional on the individual) is equal to the

individual's long-run average intake of the nutrient. More precisely, the assumption used in the NRC (1986) report is

$$e_{ij} \sim N(0, \sigma_{\varepsilon_e}^2),$$

so that $E(X_{ij} / i) = x_i$ and $Var(X_{ij}) = \sigma_{\varepsilon_x}^2 + \sigma_{\varepsilon_e}^2$, where $\sigma_{\varepsilon_x}^2$ denotes the individual-to-individual variance in nutrient intake.

Notice that under this simple model, the mean of a few days of observed intakes for an individual, denoted $\bar{X}_{i,}$, is an unbiased estimator of the individual's usual intake. However, the distribution of the observed individual mean intakes over a few days is not an unbiased estimate of the distribution of usual intakes in the group. If we assume that daily intakes for a sample of individuals in a group are observed over d days for each individual, then the variance of the distribution of observed means \bar{X} is equal to $\sigma_{\varepsilon_x}^2 + (\sigma_{\varepsilon_e}^2 / d)$. This follows from the assumptions of the measurement error model above, and implies that unless the number of days of intake d available for each individual in the sample is very large, or unless the variance of the measurement error $\sigma_{\varepsilon_e}^2$ is very small, the distribution of individual observed means will have a spread that is too large relative to the distribution of usual intakes.

Researchers at Iowa State University (ISU) have developed and modified approaches that permit estimating the usual intake distributions with a higher degree of accuracy. The method proposed by Nusser et al. (1996) is known as the ISU method for estimating usual nutrient intake distributions, and is now widely used by the nutrition community (see, for example, Beaton 1994; Carriquiry 1999; and Institute of Medicine 2000a). Software packages are available, which produce estimates of the mean and variance of usual intake in the group, as well as of any percentile of interest (Carriquiry et al. 1995). Standard errors for all quantities that take into account the design of the survey that collected the data are also produced by the software.

2. What Proportion of the Subgroup Has Inadequate Usual Intake?

Assessing the prevalence of nutrient inadequacy in a group requires estimating the proportion of individuals in the group whose usual intakes of a nutrient do not meet requirements. To determine this prevalence accurately requires information on both usual intakes and nutrient requirements for each individual in the subgroup. With this information, determining how many individuals have usual intakes less than their requirements is straightforward: one could simply count them.

Direct observation of the prevalence of nutrient inadequacy is impractical, however, because neither the requirement for the nutrient nor the usual intake of an individual can be observed. Typically, the only nutrient intake information available for a sample of individuals in a group is the daily intake of a nutrient observed over a few days (which can be adjusted at the group level, as discussed above); but nothing is known about individual requirements for the nutrient.

It is possible to show, however, that the proportion of individuals in a group whose usual nutrient intakes do not meet requirements can be approximated if the EAR for the nutrient for the appropriate gender age group and a reliable estimate of the distribution of usual nutrient intakes in the group is available. Beaton (1994) proposed a method for assessing the prevalence of nutrient inadequacy in a group that consists of simply estimating the proportion in the group whose usual intakes do not meet the EAR. Carriquiry (1999) showed that the approach proposed by Beaton (1994) can produce a nearly unbiased estimate of the prevalence of nutrient inadequacy, and recent analyses suggest that this method should be used in assessing the nutrient adequacy of group diets (Institute of Medicine 2000a). The approach, known as the EAR cut-point method, produces a reliable estimate of the prevalence of nutrient inadequacy in a group when the following assumptions hold:

- The distribution of requirements in the group is symmetric around the EAR.
- The requirements for the nutrient and the usual nutrient intake are independent.
- The variance of the distribution of requirements is smaller than the variance of the distribution of usual intakes.

Given the available information about the distribution of requirements, it appears that the above assumptions hold for many nutrients, with notable exceptions being energy and iron in pre-menopausal women. In the case of energy, intakes and requirements are highly correlated as long as individuals in the group are maintaining body weight. In the case of iron requirements, it has been established that the distribution of requirements for some subgroups is skewed with a long tail to the right. While the EAR cut-point method generally cannot be used to assess the prevalence of iron inadequacy, it is still possible to assess iron inadequacy by using the probability approach that was proposed in the NRC report (1986). To use this approach, a probability model based on the requirement distribution for iron is used to estimate the probability of inadequacy at each level of usual intake.

The analysis for this study used the EAR cut-point method to estimate the prevalence of inadequacy for each of the nutrients with an EAR, except iron; to assess iron adequacy, the probability approach is used. Some nutrients have EARs that differ by characteristics such as smoking status (vitamin C) or weight (protein). In these cases, observed intakes are divided by the EAR for each individual, the resulting ratios are adjusted to get “usual” intake-EAR ratios, and the percentages with ratios less than one are estimates of the prevalence of inadequacy.

For micronutrients without an EAR—that is, for nutrients with an AI—usual intakes distributions are presented and mean intakes are compared with the AI. However, for nutrients with an AI, it is important to note that limited inferences can be made regarding the prevalence of inadequacy. If mean intake levels are equal to or exceed the AI, it is likely that the prevalence

of inadequacy is low; but if mean intakes are less than the AI, no conclusions can be drawn about the prevalence of inadequacy (Institute of Medicine 2000a).

For food energy, neither the EAR cut-point method nor the probability approach is the approach to assessing energy adequacy. Energy requirements are expressed in terms of estimated energy requirements (EERs). Since populations in balance should have usual intake and EERs distributions with roughly equal mean values, we compare the mean usual intake of food energy to mean EER for each subgroup to assess energy adequacy. EERs are calculated based on the equations provided in the macronutrient report (Institute of Medicine 2002). For age and gender subgroups where the equations depend on an assumed level of physical activity, the low active level is assumed.

For fat, protein, and carbohydrate, tables present usual distributions of intake as a percentage of energy intake and the percentage outside the AMDR. In addition, usual intake distributions of protein and carbohydrate are presented along with percentage below the EAR.

3. What Proportion Is At Risk of Excessive Intake Levels?

To estimate the proportion of each subgroup at risk of excessive intake levels, we calculate the percentage with usual intake exceeding the UL. Because ULs have not been established for all nutrients, this research question can be addressed only for those nutrients with ULs. In addition, since some ULs refer to intakes from supplements, and since the CSFII data do not include intakes from supplements, those nutrients cannot be examined with respect to the percentage exceeding the UL.

4. How Does the Day-to-Day Variation in Nutrient Intake Vary Across Subgroups?

Daily nutrient intakes are more variable from day-to-day for an individual than they are across individuals in a group (Sempos et al. 1985; and Nusser et al. 1996). In addition, it has

been argued that the day-to-day variability in intakes is not homogeneous across individuals in a group (Nusser et al. 1996; and Institute of Medicine 2000a). For example, it has been shown that the within-individual variance of daily intake is positively associated with individual mean intake, so that those individuals with higher daily consumption of a nutrient also tend to have a larger variability of intake. A companion report investigates whether the day-to-day variability in intakes of different subgroups is a function of such factors as food insufficiency, gender and age group, and other sociodemographic characteristics (Carriquiry et al. 2004).

C. IMPORTANT DATA AND METHODOLOGICAL CONSIDERATIONS

Some important issues need to be considered when interpreting the results presented in the following chapter. The first is that the CSFII data do not include intakes from food supplements. Although we conducted a limited analysis of supplement use using data from NHANES III, small sample sizes and methodological issues associated with combining supplement use and dietary recall data limit the usefulness of that analysis.

A second important data consideration is the accuracy of 24-hour dietary recalls, and how the accuracy may vary across subgroups. Many studies have documented the underestimation of energy intakes among adult subgroups, especially among overweight adults (Mertz et al. 1991; Johannsson et al. 1998; and Schoeller 2002). To the extent that lower reported energy intakes are related to lower nutrient intake levels, the prevalence of inadequacy is overestimated for subgroups that exhibit underreporting. In addition, some studies suggest that food and nutrient intakes are overreported for young children (Devaney et al. 2004). If this overreporting of energy intakes is associated with higher nutrient intakes, the prevalence of inadequacy for these subgroups would be underestimated.

Another data issue concerns folate intakes. The data used in this analysis are from the 1994-1996 and 1998 CSFII, which were collected prior to the mandatory folic acid fortification of the

food supply. Thus, folate intakes in this analysis underestimate current folate intakes. In addition, folate intakes from the CSFII are not in Dietary Folate Equivalents, which are the form in which the folate DRIs are expressed.

In addition, usual fiber intake from the CSFII is the intake of dietary fiber, while fiber requirements are expressed as total fiber, defined as the sum of dietary fiber and functional fiber. Thus, intake of dietary fiber is less than total fiber intake. Estimates suggest that total fiber intakes are, on average, 5.1 grams higher than dietary fiber intakes (Institute of Medicine 2002).

Finally, in interpreting the nutrient adequacy results for NSLP and SBP participants, it is important to note that the NSLP and SBP programs underwent significant changes in the mid 1990s, with the design and implementation of the School Meals Initiative for Healthy Children. In particular, USDA regulations in June 1995 required school food authorities to prepare meals that met new nutrition standards for fat, saturated fat, and other key nutrients. These requirements were not imposed on most schools during the period covered by the 1994-1996 CSFII, so dietary intakes of NSLP and SBP participants surveyed during that time period may not accurately reflect current intakes of program participants.